# TROPICAL AGRICULTURE

THE OFFICIAL JOURNAL OF THE
IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

VOL. XXI, No. 8. AUGUST, 1944. PRICE 6d.

CONTENTS

| | PAGE |
|---|---|
| The Folly of Deep Ploughing ... ... | 141 |
| Insect Pests of Cacao in Peru ... ... | 143 |
| Notes on the Nomenclature, Classification and Possible Relationships of Cacao Populations | 144 |
| Weed Control in Louisiana ... ... | 159 |
| Chemical Notes ... ... ... | 160 |

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, TRINIDAD, B.W.I.

Cables :: "Stomata." | Phone :: 0365

*TROPICAL AGRICULTURE is published monthly at the Imperial College of Tropical Agriculture, St. Augustine, Trinidad, West Indies. Advertisement and Subscription rates can be obtained at the College from the Editor, or from the Secretary of the College, Grand Buildings, Trafalgar Square, London, W.C. 2, England. The Editor will be glad to consider authoritative articles for publication. It is understood that opinions expressed or recommendations made in signed articles or in articles of which the source is named are those of the author and do not necessarily represent the policy or opinion of the College Authorities. Increasing numbers of inquiries are being received from the various parts of the tropics which can be answered only by persons possessed of an intimate knowledge of local conditions. Enquirers should first satisfy themselves that their local Department of Agriculture is not able to supply them with the desired information before communicating with us. Correspondence which will be replied to is invited on all other matters pertaining to tropical agriculture, science and development.*

## THE FOLLY OF DEEP PLOUGHING

FEW events in recent agricultural history may prove to be so important as the publication just a year ago of a remarkable book written by an American Farmer.* The book is entitled "Plowman's Folly," and the name of its author is Edward H. Faulkner, a one-time county agent in Kentucky and Ohio and a trained experimenter. It constitutes perhaps the most serious challenge to agricultural theory that has been advanced in recent years; its teachings may well alter the established practice of land cultivation, for it claims to prove that the traditional mouldboard plough severely injures the soil and "is the least satisfactory "implement for the production of crops" that has yet been proposed.

The mouldboard plough was invented in England in the 18th century, and was designed to turn over the soil so as completely to bury everything that lay upon it, leaving a clean bare surface which could be worked up into a powdery tilth well adapted to the sowing of grain. At that time England was mostly covered by forest, and the cleared lands had not been completely subdued so that weeds competed severely with the growing crop; nor could the then-known methods of hand-cultivation adequately cope with them. The introduction of the mouldboard plough into such an environment was a godsend. Pulled by oxen, the new implement could completely invert the soil and effectively bury perennial weeds and small shrubs so as to give the sown grain and roots chance to get away before the wild vegetation recovered sufficiently to compete with them. A farmer who previously could only manage a few square rods of land could, with the aid of the new plough, now raise food on several acres.

Agriculture in England in those days needed to be extensive; the people were continually near starvation and crop production was quite inadequate to meet the requirements of the increasing population. The mouldboard plough thus marked the beginning of a new agricultural era; it rapidly became symbolic of all that

**Plowman's Folly*; E. H. Faulkner: Grosset and Dunlap, publishers, New York, by arrangement with University of Oklahoma Press: 1943.

*See also* article by Louis Bromfield, "The Evangelist of Plowman's Folly", in *Reader's Digest*, December, 1943, pp. 35-39.

was progressive and good in crop production. In later years, when agriculture gradually changed from extensive to intensive farming as the world's supply of cultivable land began to fail, the plough still held sway, unchallenged in its presumed usefulness, though the circumstances that had initially warranted its introduction were entirely altered.

The main charge which the author of "Plowman's Folly" lays against the mouldboard plough is that the act of soil inversion places crop residues and green manures, and all else added as amendments to the soil surface, below the reach of the roots of the crop that is being grown. It creates a highly absorbent layer below the surface which, through its large water-retaining capacity, interferes with upward capillary movement of soil moisture, in that it literally produces a "sandwich" layer between soil that is rapidly drying out above and moist soil below. Furthermore, under these conditions, the organic matter does not decompose properly. The carbon-dioxide it generates by oxidation sets up a toxic subsoil concentration which adversely affects the micro-organisms controlling decay, and may even penetrate into the rooting zone above. The mass of sour buried vegetable matter takes an inordinately long time to liberate its store of nutrients, and the growing crop may absorb very little of these valuable by-products. The bare exposed soil material above the sandwich organic layer is easily eroded by water and wind, and constantly exposed to excessive evaporation from wind and sun. An artifical condition of drought exists between the buried organic layer and the sun-baked surface. In the long run the topsoil is entirely destroyed and lost. Out of these mishaps have emerged such catastrophies as the great Dust Bowl disaster of the 1930's when millions of acres of agricultural land had to be abandoned in the south-central States of North America.

The correct procedure to follow in cultivation, according to Edward Faulkner, lies in *the use of the heavy disc harrow which rips up and loosens the surface but does not turn under the grass-sod, stubble or cover-crop*. Capillary uplift of water is thus not arrested, and evaporation from the surface is greatly reduced by the blanket of mulch that covers it. Furthermore, the organic mulch prevents run-off during rains and hence loss of soil through erosion is lessened. His contention therefore is that we should increase the depth of our soil from the top downwards rather than from the bottom upwards which is the method attempted when trash, litter and manure are buried deep. He advocates working from the top by piling up an accumulation of decaying organic matter which is Nature's way as seen in forest and meadow. Indeed the first cause of Faulkner's realisation of the evil done by the mouldboard plough was his observation that crop-plants growing in the hedgerows resist drought markedly while the plants out in the bare baked fields wither and die. In the hedgerows the ground has not been ploughed and the surface is covered by a mulch of decaying vegetation and loose soil, circumstances which help to conserve soil moisture.

The ideas engendered in Faulkner's mind were put to exhaustive test by him, first during the years 1930 to 1938 in his back garden where, to quote his own words, the soil was "better suited to brickmaking" than to the growing of vegetables, being just harsh "cellar dirt"—a house builder's dump—devoid of all organic matter. It was so hard when dry that a sharp spade made no perceptible impression on it, and the clods were as "sharp as broken stone", and so sticky when wet that it clung to his boots in lumps "as big as he could carry". By a system of surface mulching with dead leaves, coupled with a process of working decayed weeds and vegetable residues into the upper layer and not burying them, the soil had become so much improved in seven years that the surface was "as granular as sugar", and every crop planted thrived and produced as well or better than crops grown by neighbours on inherently much superior soil.

The success of the garden experiment inspired a much larger test on a field scale on derelict farm-land in Ohio. Here again the method practised was to incorporate green manures into the soil surface with a disc harrow, and to plant or sow direct onto the trashy land, usually, however, at spots compacted by a crude implement specially designed for the purpose of marking out the planting sites in rows. The green manure mainly used was rye, which gives two crops a year. Alternatively weed growths were used as mulch.

It would appear from published reports that Edward Faulkner's method of cultivation has been brilliantly successful; "his almost unbelievable yields make his experimental plots commercially profitable", to quote only one report. Following the publication of his book, "the hottest farming "argument since the tractor first challenged the "horse has been started",. . . . and "returns on "the great debate had begun to come in:—they "were very favourable to Faulkner."*

A careful study of ploughing *versus* new methods of soil cultivation has been undertaken on experimental farms in Iowa by officers of the State and of the United States Departments of Agriculture.* The new methods were disc-harrowing, as advocated by Faulkner, listing and subsoiling, all of which loosen the soil without turning it over. One object was to leave the stubble on the surface so as to afford a check to erosion; another was to provide decaying organic matter to act as manure. In the Iowa tests so far the new methods are stated to have produced bigger soyabean crops, to have saved one-third to one-half the man and machine power needed for ploughing, to have reduced erosion from 34 to 10 tons of soil lost per acre, and to have kept down weeds better than customary ploughing methods. Finally, "the

*"*Time*"; 28 Feb. 1944: *See* "Shall we discard our ploughs"? by G. M. Browning, R. A. Norton and J. B. Davidson, *Farm Science Reporter*, Iowa State College, Ames, Iowa, 1944, 5, No. 1, pp. 7-10.

"investigators decided that ordinary ploughing is "an expensive luxury; they concluded that "farmers and machinery manufacturers should "investigate new types of machines before "investing heavily in mouldboard ploughs which "may be obsolete long before they are worn out".*

The author of "Plowman's Folly" has thus created a problem for the engineers who make agricultural implements, namely, to provide heavy sharp disc harrows that will rip up and loosen but leave the soil unturned, and also lay and chop up a wide range of kinds of cover-crops from tall grass to bushy and trailing legumes, and from weeds even to woody shrubs, and moreover, implements that will satisfactorily prepare all kinds of soil under all sorts of conditions by a process of top working with organic mulch.

* *Ibid.*

The fame that Edward Faulkner has already acquired in U.S.A. is "a sign that the revolution in agriculture is being recognised"†. . . A famous agricultural economist in Washington is quoted as saying "The civilisation of this country is "founded upon nine inches of topsoil; when that "is gone, civilisation will go with it."† This remark surely applies to countries other than those of the North American Continent; it applies also to every part of the world where civilised man is striving to preserve his civilisation, while "the "surface of the earth is strewn with ruins of "nations and of civilisations which destroyed "themselves by wearing out the soil."†

F.H.

†"*Reader's Digest*"; *loc. cit.*

## INSECT PESTS OF CACAO IN PERU

BY

J. E. WILLE

(*Translated from the book "Entomologia Agricola del Peru" by J. E. Wille, Lima,* 1933, *p.* 185-191, *and reproduced by kind permission of the author and publishers*)

Cacao is grown in Peru in almost all the valleys of the Montaña region and in some of the coastal valleys north of the Chicama Valley. In all these districts it is attacked by numerous insects. Mention has been made on previous pages of ants of the genus *Atta*, which attack the leaves of cacao and other tropical crops; of the aphid *Toxoptera aurantiae* Boyer, which infests leaves and shoots; the mealy-bug *Pseudococcus citri* Risso on foliage and fruit; and of the weevil *Araecerus fasciculatus* de Geer, which attacks the dry beans of cacao and coffee.

The outstanding insect pests attacking cacao specifically are bugs of the family Capsidae (Miridae), belonging to several species of the genus *Monalonion*, notably the "mosquilla", *M. dissimulatum* Dist. This bug occurs also in Central America, Colombia and Ecuador. In Peru it is found throughout the Montaña and in the coastal valleys. These insects, which have mouth-parts adapted for piercing and sucking, attack the young shoots and twigs and especially the young fruits. The affected parts are marked by pustules and black warty spots, which are especially noticeable on young green fruits, and they wilt and die. Damage may be very extensive, resulting in a complete loss of crop.

The adult insect is slender, 10 to 15 mm. long, reddish-yellow with black spots and bands on head and wings. The nymphs are darker than the adult and marked by only a few reddish spots. The eggs are laid singly on young fruits especially, but also on tender twigs. The maximum incubation period is one week. The nymphs live on the shoots and fruits, piercing and sucking them, causing staining. There are five nymphal stages, extending over three weeks. The adults live for two or three months. Egg laying occurs throughout the year and all stages of development, eggs, nymphs and adults, may be found together.

Ecological conditions favourable to *Monalonion* are high temperature and humidity and abundant shade. It does not thrive on trees exposed to the sun, and causes most damage where the trees are closely spaced and heavily shaded. The best methods of control that can be recommended are therefore cultural, with the object of increasing exposure and reducing humidity by spacing the trees sufficiently and by reducing shade. Direct measures of control include burning the bugs by passing a flame over infested branches. In Montaña torches are easily made with "waipe" soaked in kerosene on a long pole. Nicotine sulphate or an emulsion of kerosene and soap may be used. There is no known method of biological control, using natural enemies of the bugs.

In addition to *Monalonion*, bugs of other families infest cacao, including *Epicoris corrosus* H.S. and *Dinocoris* sp. of the family Pentatomidae, *Parajalysus spinosus* Dist. in the Neididae, and *Tigava convexicollis* Champion in the Tingitidae. These insects cause damage similar to that of *Monalonion*, which they resemble also in habits.

The cacao thrips, *Selenothrips rubrocinctus* Giard, is an important pest of cacao in Montaña. (As this insect is well known in other countries, the account of it is not reproduced here—Ed.)

Finally, among pests of cacao pods in Montaña mention should be made of rats, "pericotes" and several birds, especially wood-peckers, all of which bore holes in nearly ripe fruits. Clean cultivation and trapping reduce damage by "pericotes" and rats, but against birds the only known remedy is to employ boys to scare them off when the fruits are ripening.

# NOTES ON THE NOMENCLATURE, CLASSIFICATION AND POSSIBLE RELATIONSHIPS OF CACAO POPULATIONS

BY

E. E. CHEESMAN

(*Botany Department, Imperial College of Tropical Agriculture*)

## 1. Introduction

The nomenclature of the cultivated cacaos is far from satisfactory, because many of the terms in common use (such as "Forastero", "Amelonado" and so on) do not identify unequivocally the cacaos to which they are meant to refer. Confusion is due partly to different interpretations by different writers, but for the greater part it simply reflects the imperfections of the existing system of classification.

So long as fundamental knowledge of cacao genetics is lacking, there can be neither a perfect natural classification nor an entirely satisfactory nomenclature. Nevertheless, in the light of knowledge acquired in the last twenty years or so, it should be possible to effect some improvements in both respects and in particular to attain a greater uniformity in the use of common terminology.

The notes offered here are somewhat disjointed because they attempt to deal with a large subject in the absence of the data necessary for a comprehensive monograph. They are presented because recent investigations of Amazonian cacaos by Pound (1938) have thrown new light on distributions and possible relationships, yet (so far as the writer is aware) no review of the whole range of cacaos has been published since Pound's notes were available. They should be read as a discussion of what we still need to know about the systematic botany of cacao, as much as a modest attempt to simplify slightly the classification and nomenclature of the crop.

## 2. Criticism of Current Usage

The system of classification in general use at present starts by dividing all cacaos into two classes called Criollo and Forastero respectively, and proceeds to subdivide the Criollos according to their geographical distribution and the Forasteros according to the shape of their fruits. Some of its imperfections have been pointed out by van Hall (1932) who reproduces it concisely as follows:

1. Criollo
2. Forastero
   - (*a*) Angoleta (or Liso)
   - (*b*) Cundeamor (or Cundeamor verrugosa)
   - (*c*) Amelonado
   - (*d*) Calabacillo

The distinction here recognized between Criollo and Forastero cacaos is universally accepted both in the field and on the market, and inasmuch as it marks off the Criollo cacaos as a distinct group is sound. It oversimplifies the position, however, in making the term "Forastero" cover all cacaos that are not Criollo. The "non-Criollo" group in fact provides well over 90% of the commercial cacao of the world and includes so many diverse forms that one inclusive term for it is practically useless.

The subdivision of "Forastero" is not only of little practical value but actually harmful because of the confusion caused when Angoleta, Cundeamor etc. are regarded as "varieties" of cacao. It cannot be too strongly emphasized that these terms apply to nothing but the *shape of the pod*; and while they may have a certain use in describing members of mixed populations, they have no "varietal" significance at all. Everybody admits that these so-called "varieties" cannot even be distinguished in the field. To quote van Hall again: "The different types are not sharply separated from each other. They form a continuous series, beginning with the finest *Angoleta*, which is very much like the Criollo, and running through the Cundeamor and the Amelonado to the smoothest *Calabacillo*."

The word "variety" has been carefully avoided wherever possible in these notes, and should be treated with similar conservatism in all botanical literature dealing with cacao. In popular usage this word can cover all sorts of plant populations from subspecies to clones, and in connexion with cacao it is in fact applied by different writers to populations of entirely different ranks. When properly used in a botanical sense, however, it carries certain implications about the status of the population to which it refers. As one of our immediate problems happens to be the determination of the relative ranks of recognizably different populations, the use of any term with formal implications is undesirable at the present stage. Later it may be possible to define what legitimately constitutes a "variety" of cacao.

## 3. The Material to be Classified

The whole assemblage of wild, semi-wild and cultivated cacaos presents certain general features which should be recognized at the outset, as helping to define the problems of classification and to put them into correct perspective.

Of these the most important is that it forms *one interbreeding population*. The question whether it is to be regarded as one botanical species or more than one will be discussed in a later section. The point for the moment is that, so far as our knowledge goes, all members of the genus *Theobroma* that can properly be called "cacao" are interfertile. Furthermore they show a high rate of cross-fertilization in the field, which not only

leads to rapid mingling when different local populations are brought together, but also implies that even a local race which may have evolved in isolation will be a more or less heterogeneous collection of heterozygous individuals.

An essential fact, hitherto ignored in formal classification though admitted by several writers in their discussions of "varieties", is the existence of an important group of cacaos that are *hybrid populations of relatively recent origin*. It is clearly important to distinguish between such mixtures and "pure" populations which have evolved in comparative isolation, so far as we can judge. Thus in studying cacaos geographically we find ourselves dealing with very different degrees and ranges of variability, according to the provenance and history of the local populations concerned. It is exceptional to find any population in which variation is not apparent, but in the "original" cacaos of these countries where the crop is indigenous or very anciently established the variation is much narrower than it is in the recent mixtures.

Another point to be noted is the differing degree to which various cacaos have been *influenced by Man*. At one end of the scale, the Criollos of Central America have probably been subject to human selection for at least three thousand years, and possibly much longer. They may correctly be described as crop plants. At the other end, Pound (1938) has described cacao tree populations along the upper Amazon and its tributaries which for the most part seem to be most appropriately called "semi-wild". In that region some at least of the cacao trees found in the forests are probably truly wild and indigenous, but the groups found along the river banks are influenced by man, if only to the extent that by leaving cacao trees standing when clearing a patch for his habitation man has altered the ecological conditions governing survival. If this kind of association has been going on, as seems probable, for some centuries these Amazonian cacaos do not form an entirely "natural" population, though they cannot be described exactly as "cultivated". It is apparently from this condition that Brazilian cacao was taken more closely into cultivation some two centuries ago, spreading subsequently to West Africa by deliberate introduction.

Of truly wild cacaos, entirely uninfluenced by man, we naturally know little because of the difficulties of collection in districts quite unlikely to have been influenced by human settlement. Among the various "wild cacaos" that have been described, some are species of *Theobroma* clearly having no close relationship with the true cacaos. Others seem very likely to represent escapes from cultivation, and this applies particularly to the wild cacaos of Central America, where the crop is undoubtedly ancient and has had plenty of time to escape and establish itself, in favourable situations, thoroughly enough to appear indigenous.

Thus, while there appears no doubt that true cacaos do exist in a wild and completely natural state, the evidence that can be obtained from "wild cacaos" about the evolutionary history of the complex has to be treated with caution.

Among the cultivated cacaos the correlation of type with geographical distribution tells us a good deal, but it is rapidly becoming obscured by introductions from one region to another, followed by mingling through natural cross-fertilization in the plantations. During the last fifty years there has been a tremendous amount of plant exchange between the cacao growing countries, both small and large, of the New World—most of it unrecorded. In another fifty years at the present rate, or even more quickly with the increasing interest being shown in cacao cultivation, it may be almost impossible to identify the "original" cacaos of any of the Central American or South American countries. Fortunately Preuss (1901) wrote rather detailed descriptions of the types observed on his journeyings at the beginning of the century, and most subsequent writers have drawn extensively on Preuss for their treatment of cacao "varieties".

The cacao populations of Old World countries naturally do not enter much into the present discussion, since they are all of American origin and in most cases their provenance is either recorded or can be inferred with some exactness from their constitution.

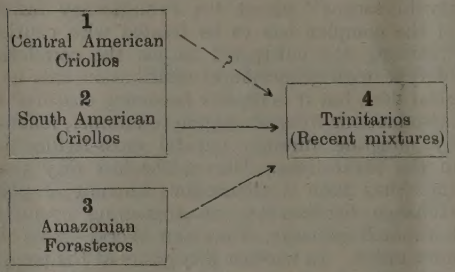
### 4. The Main Groups of Cacao

Avoiding the ambiguous word "variety", the material for classification is to be regarded as made up of a large number of local populations which, although they tend to intergrade, have each certain characteristics by which they can be recognized. The smallest populations recognizable as distinct are then to be grouped accordingly to their apparent relationships. When this is done, it is easy to recognize four main groups of cacaos, and up to the present only four, although there is still a possibility of new forms coming to notice that will not fit into the scheme. For the four groups I prefer the following terminology:

1. Criollo
   - (*a*) Central American Criollos
   - (*b*) South American Criollos
2. Forastero
   - (*a*) Amazonian Forasteros
   - (*b*) Trinitarios

This grouping preserves the traditional distinction between Criollo and Forastero or "non-Criollo" cacaos but makes provision among the latter for separating hybrid populations of recent origin (Group 2b) from "pure" non-Criollo populations (Group 2a). It is also in line with current usage, at least in the British Colonies, where a distinction is well recognized between the Trinitarios grown in Trinidad and elsewhere, and the Forasteros that make up the bulk of the West African crop.

The relationships of the four main groups may be expressed diagrammatically as follows:




Formal acceptance of the suggested terminology, however, involves some re-definition of names. When the terms "Forastero" and "Trinitario" were first used they were synonymous, and both applied to the hybrid group here called Trinitarios. The cacaos now called Amazonian Forasteros were at that time almost unknown, and since they became important they have never received any distinctive name, but the term "Forastero" has been extended to cover them, whilst the term "Trinitario" has retained its original significance. To be pedantically accurate, now that their distinctness is recognized, the Amazonian cacaos ought to be given an entirely new group name. But they have now been so long and so universally classified as Forastero that it is much more convenient to re-define that term than to attempt the introduction of a new one. The next section is devoted to the re-definition, and reviews the history of the names so far as is necessary to justify their adaptation to modern needs.

## 5. History and Application of the Terms Criollo, Forastero and Trinitario

"Criollo" as applied to cacao has long carried a meaning different from its original signification of "native". First used in Venezuela to distinguish the kind of cacao that was regarded as native there from another kind introduced from Trinidad, the name remained attached to the same cacao when it was carried to other countries, including Ceylon and Java. To the trade this cacao, also called Caracas, was well known as a high quality product with plump beans, light "break" and fine aroma. By natural extension the term Criollo came to be applied to similar high quality cacaos from other countries. "Nicaraguan Criollo", for example, means "a Criollo type cacao from Nicaragua" rather than "the cacao native to Nicaragua". In that particular case both meanings happen to be applicable, but by further extension such terms as "Ceylon Criollo" and "Java Criollo" can be used quite properly, although taken literally they would be ridiculous. In Spanish-speaking countries the original meaning very naturally persists, though the extended and specialised meaning is generally understood. Thus there are still occasional possibilities of confusion, which would be more common but for the fortunate coincidence that the "native" or original cacaos of all the Central American countries and Mexico, as well as Colombia and Venezuela, happen to be Criollos in the trade sense and the botanical sense as well as literally.

The Criollo cacaos are very various and consequently difficult to define with precision, yet they form a sufficiently well-marked group to be as a rule easily recognizable in the field on the sum of their characters. Their fruits may be either red or yellow when ripe, and are usually deeply ten-furrowed, very warty and conspicuously pointed. The fruit wall is relatively thin and easy to cut. The seeds are plump, and the fresh cotyledons white or pale violet in colour;* they ferment quickly, and the nibs of the prepared cacao are usually described as cinnamon-coloured. Further discussion of the Criollos occurs in a later section.

"Forastero" (meaning "exotic") is naturally antithetic to Criollo, and came into use in a "varietal" sense at the same time, to distinguish from the "native" cacao of Venezuela another kind introduced from Trinidad. The date of this introduction is given by Perez Arbelaez (1937, p. 82) as 1825, and there can be little doubt that the original Forastero of Venezuela was the mixed Trinidad population much as we know it today. The history explains why it was (and is) also known in Venezuela by the alternative name of "Trinitario". To the trade, the important thing about this cacao was that it was of lower quality than the Criollo, with more or less flattened beans, darker "break" and coarser flavour. Hence a natural extension of the name in the trade sense was to cover all cacaos of similar quality. For some time this meant in practice that the term covered chiefly the cacaos of Trinidad and Ecuador, both of relatively high grade although inferior to the Criollo. Later, as large cacao industries developed in West Africa and Brazil, the produce of those countries also was put into the Forastero class, though of considerably lower quality than the original Forastero of Venezuela. Botanically however, the cacaos of Ecuador, Brazil and West Africa are distinct from the original Forastero of Venezuela, and the lumping of them all together has led to very great confusion in the economic botany of cacao in general. Therefore we now need a nomenclature which will recognize the distinction and help to dispel the confusion.

Obviously the academically proper course would be to find or invent a new name for the group of cacaos characteristic of Brazil, West Africa and Ecuador and restrict the term "Forastero" to its original owners. But this procedure is open to the objection that for many years now these same cacaos have constituted some four-fifths of the

*My attempt in 1932 to define Criollo cacaos by complete absence of pigment in the cotyledons was based on insufficient knowledge and will not serve. It now seems clear that we have to admit as true Criollos a number of forms having light purple or violet cotyledons. How dark they may be at the maximum is still not known.

"Forastero" on the market. Thus *de facto* though not *de jure* the name may be said to belong to them, and any attempt to restrict it to its original scope, would cause more confusion anew than it would clear up. It therefore seems desirable to put convenience before historical accuracy and to allow the Brazilian, Ecuadorian and derived West African cacao populations to retain the stolen name of Forastero, but to prefix it with the adjective "Amazonian" to distinguish them clearly from the original Forastero of Venezuela.

Amazonian Forasteros, like Criollos, are very various and equally difficult to define but also easy to recognize. So far as known at present their fruits are always green, ripening yellow, though there may be traces of red pigmentation in some forms. The fruit varies from a shape difficult to distinguish from some Criollos to that commonly called Amelonado, which is inconspicuously furrowed, not at all warty, and round-ended or very bluntly pointed. This Amelonado type of pod happens to be the commonest in cultivation, but need not on that account be regarded as "typical" of the whole group, since its present abundance is due to the fact that recent large expansions of cacao-growing in West Africa and Brazil happen to have been made with one particular kind of cacao and not with other members of the same group. In most the fruit wall is relatively thick, and it often has a woody layer difficult to cut. The seeds are more or less flattened, and the fresh cotyledons usually dark purple in colour, often almost black but in some races relatively pale, though possibly never as pale as the darkest Criollos. Like the Criollos, this group is further discussed in a later section.

"Trinitario", as mentioned above, was in its original application synonymous with "Forastero" because the cacao that was "foreign" in Venezuela was "cacao from Trinidad". But whilst the term Forastero has become so extended in popular usage that it no longer has any precise botanical meaning (unless prefixed by some qualifying epithet as in the case of "Amazonian Forastero") Trinitario has fortunately retained a narrower meaning, and is therefore a better name for the population originally designated Forastero. Yet just as "Criollo" and "Forastero" have lost their original meanings of "native" and "foreign" so there can be no objection to extending "Trinitario" to cover more than "the cacao from Trinidad". The origins and constitution of Trinidad cacao are discussed in a later section, where it is shown that it is probably a recent mixture of Criollo and Amazonian Forastero stocks. Similar mixtures are at the present time arising *de novo* in several countries where introduced Forasteros have been planted among established Criollos, and it is convenient to classify all these as Trinitarios.

### 6. Criollo Cacaos

Within the main group of cacaos called Criollo it is possible to distinguish a large number of forms, and several rather different populations. These are classifiable on a geographical basis, in the first place into two sub-groups which we may call Central American and South American respectively. Pending further investigation of both sub-groups it is difficult to say whether there are essential differences between them, or whether they in fact intergrade, but for the present their separation is convenient because they present, on the whole, rather different facies.

*Central American Criollos* are found in Southern Mexico, Guatemala, Salvador and Nicaragua and probably occur also in Honduras, Costa Rica and Panama (though the commercial cacao of Costa Rica and Panama is Trinitario of recent introduction). They are undoubtedly of ancient cultivation and are often assumed to be indigenous, though on this point the scanty evidence allows differences of opinion.

The commonest pod shape is long and narrow, conspicuously furrowed and very warty, with a prominent five-sided point. The cotyledons in the fresh seed are commonly white, but according to some authorities sometimes pale violet.

In vegetative habit a considerable proportion of the trees differ from all other cacaos so far described in having no jorquette. The seedling starts with a spiral phyllotaxis, but the spiral gradually opens into a two-ranked arrangement without any forking of the trunk, and the whole tree has much the same kind of branch system as a fan cutting. This habit, however, is not diagnostic because some trees apparently quite as truly members of the same population, show the jorquetting habit.

In other characters there is wide variation. In pod shape the population includes certain forms so extreme that they have been regarded as distinct species, though in my opinion they are genetically unimportant (see discussion below of *Th. pentagona* and *Th. leiocarpa*). Between the extremes there is variation in depth of furrowing, degree of wartiness, and presence or absence of the constriction near the stalk end commonly called "bottleneck". The most constant feature in shape seems to be the five-sided point, but even this varies in expression and becomes obscure in some extreme forms.

In colour, the pod may be either green or whitish-green when unripe, ripening to yellow; or it may be partially or entirely red, and red colour may apparently be associated with any pod shape. Preuss mentions both red and yellow fruits among the Criollos of Guatemala, Salvador and Nicaragua, but unfortunately without comment on their relative abundance. In Mexico the unpigmented or only slightly pigmented forms predominate, and there is a predominance of green-podded types among the introductions from Nicaragua to Trinidad made by Hart fifty years ago. Predominance of unpigmented pods may possibly be a characteristic of the Central American population, but fully red ones are by no means uncommon.

The seed is always plump, but varies much in size from country to country. According to Preuss the seeds of Salvador Criollo are small, but very round. A similar description might be applied to Mexican Criollo, but Nicaraguan "cacao del pais" includes the largest seeded forms of all known cacaos. Nothing has been recorded about tree to tree variation in this respect, but it would appear to be much less than the variation between the local strains.

These cacaos are not of much present commercial importance, because the countries in which they grow are small producers, and the Central American Criollos therefore do not enter export markets at all. To the botanist however, they are of great interest and potential usefulness. Their scientific interest lies in the probability that these are of all cacaos the most influenced by long cultivation and selection by man. Their practical significance is illustrated by the history in Trinidad and Tobago of some Nicaraguan Criollos introduced by Hart in 1893: some of the best of the Imperial College selections, made forty years later, are either surviving individuals of Hart's introductions or obviously descendants of them.

On these grounds any information that can be obtained about the Central American cacao population is botanically important; but unfortunately it is apparently already too late for any quantitative genetical survey to be made comparable with that carried out by Pound on the Trinidad population in 1930-35. In all the countries concerned, introduced cacaos of other groups are finding more and more favour with planters on account of their greater vigour. Although there is in these countries a strong quality tradition, and some prejudice against the introductions on that ground, the Criollo plantations are on the decline, and in most cases on the verge of extinction. Thus as a rule only qualitative notes can be obtained, and it is a matter of some urgency that all possible information and material should be collected while relics of the population still exist.

Almost the only region where considerable areas of pure Criollo can still be found is the Mexican State of Tabasco, and even there the population is falling, since practically all the new plantings of the last 12 to 15 years have been of introduced Trinitarios. In Chiapas (in the famed Soconusco region) there are still Criollo fields, but recent plantings are either of Trinitarios or of an Amazonian Forastero type.

In 1943 G. E. L. Spencer of the Imperial College of Tropical Agriculture spent several weeks seeking out and collecting Criollo cacaos in Guatemala, Honduras and Nicaragua, and found conditions greatly changed from those described by Preuss in 1901. In Guatemala he was able to locate only scattered Criollo trees, and in Nicaragua found that the plantations around Rivas are now so mixed that pure Criollo individuals can only be determined with difficulty. In Honduras no Criollo was found, but a cacao was collected near Lancetilla which appears to be an Amazonian Forastero of fairly recent introduction but already escaped from cultivation and established in the wild.

A more intensive search, with more time available would doubtless establish the existence of quite numerous pockets of Criollo trees still surviving in the Central American countries but in general terms it does not seem to be an exaggeration to say that the original cacao populations south of Mexico have already disappeared. At least, the Criollo where it occurs is so intermixed with introduced cacaos of other groups that determination of the characteristics of the original population is extremely difficult.

*South American Criollos.* What appear to be the original cacaos of Colombia and Western Venezuela, possibly indigenous in Colombia, form the second group, which is clearly related to the first and here separated as much for convenience as by conviction.

This group is identical with what most authors call the "variety" Venezuelan Criollo, but the term group is preferable on account of the wide variation which exists here as elsewhere throughout the cacaos. A recent account of Venezuelan cacao by Perez Arbelaez (1937) describes some of the variation, and it has previously been noted by Preuss and others. As in Central American Criollos, the pods are commonly long, relatively narrow and pointed, conspicuously furrowed and warty. They are, however, frequently less sharply and slenderly pointed than those of the Central American group. Van Hall (1932) says definitely that the long tapering point of Nicaraguan Criollo is longer and sharper than in the other Criollo varieties, and even when allowance is made for the fact that my Central American group is wider than his variety, I think that the statement remains generally true. Some illustrations of Venezuelan Criollo show quite a blunt point. Typical Venezuelan Criollo is supposed to be without "bottle neck", and when this constriction of the pod towards the stalk end is present the tree is usually classified as Cundeamor, but in my opinion this is a useless character in classification, since "bottleneck" can be found in some degree in every group of cacaos, both Criollo and Forastero, and varies widely from pod to pod on the same tree.

A smooth-podded form called "Porcelano" occurs among Venezuelan Criollo and the Java Criollo derived from it, which seems to be directly comparable with the *leiocarpa* form occurring among Central American Criollos, but no *pentagona* form has been recorded from South America.

One's general impression from the literature and from samples seen is that red pigmentation of the pod wall is much more general in this group than among Central American Criollos. In fact in Venezuela it is a red-fruited kind that is called "Criollo legitimo", which seems to imply that it is or at least at one time was, the dominant element in the mixture. The importance of red pigmentation

can easily be over-stressed in the discussion of relationships in cacao, but as a conspicuous character it cannot be entirely ignored neither is it entirely unimportant.

It is generally agreed that the colour of the cotyledons within the seed may be either white or pale violet, but is never dark purple. Some authorities hold that white cotyledons are found in yellow pods and violet ones in red pods, but according to others no such rule exists.

The seed is always plump, but very little seems to have been recorded about its variation in size, either from tree to tree or from district to district.

Though of slightly greater direct commercial importance than their Central American relatives, the South American Criollos are produced only on a small scale. Their great interest to the botanist is as putative parents of the Trinitario group, to which, if our present working hypothesis is correct, they have contributed most of the genes controlling quality.

Detailed knowledge about the range of variation in the South American Criollos would undoubtedly be of value in the selection of parents for cacao breeding programmes. The difficulty in the way of obtaining such information is similar to that encountered in the study of the Central American Criollos—the difficulty of finding in any place convenient for observation a tree population which is large enough to be a representative sample of the group and at the same time pure in composition. There is already so much admixture of Trinitario in most of the plantations of Venezuela and Colombia that determination of the genuine original type needs very great care and in some cases proves impossible.

This difficulty is illustrated by some observations made in 1943 by J. E. Salinas in the Cauca Valley, Colombia (unpublished data, I.C.T.A.). Salinas used three plots, 280 trees in all, on three different estates selected as typical of the commercial cacao grown in the Cauca Valley, which is still predominantly Criollo but becoming more and more mixed with Forastero forms. The trees were examined and recorded by methods similar to those used by Pound for Trinidad cacao (Pound 1932).

The records of cotyledon colour serve to indicate roughly the extent to which mixture has taken place. Only 137 trees, or almost exactly half the population, were recorded as having all white beans. The remainder were made up of 36 light purple beans, 11 with purple and 97 with mixed purple and white beans. It is clearly impossible to define the limits of the Criollo component in such a population. The trees with white beans only could safely be assumed to be pure Criollos, but they probably do not by themselves give a complete picture of the group, because it is likely that some at least of the trees with lightly tinted beans are Criollo, and that a considerable proportion of those with mixed beans are also Criollos, the mixture being due to cross-pollination. Cross-pollination is to be expected, and provides the best explanation of the fact that 69 of the 97 trees with mixed beans were classified as having more than 50% of their beans white. If those 69 are accepted as Criollos, the total Criollo component in the plots under investigation is not less than 70% and may be over 80% of the population, the estimate depending on the classification of the trees with pale beans. This is as nearly as we can estimate it without knowing how much cotyledon pigmentation occurs among pure Criollos, and this population shows how very difficult it has become to answer that question.

An interesting feature of Salinas's survey is that the distribution curves for all the dimensions measured approximate as closely to the normal form as could be expected from the size of sample. This fact enables us, with due reservations, to compare the Cauca Valley population with that of Trinidad, especially from the point of view of range of variation, and the comparison gives rather surprising results. In Table I the minimum, maximum and modal figures obtained by Salinas are compared with those obtained by Pound from a larger sample (950 trees) of Trinidad cacao in 1932 (Pound 1933). The similarity in range is more striking than the differences in some of the modal values. We cannot infer that the range would be equally wide in an uncontaminated Criollo population, but the significant fact is that we have nowadays to form our ideas of the original Criollo population largely from observations of this kind, and caution is indicated in accepting anybody's definition of a "typical" Criollo.

**Table I**

| Dimension | Minimum | Maximum | Mode |
|---|---|---|---|
| *Length of pod*: | | | |
| Colombia | 9 cm. | 22 cm. | 18 cm. |
| Trinidad | 10.5 cm. | 23.5 cm. | 16 cm. |
| *Diameter of pod*: | | | |
| Colombia | 6 cm. | 12 cm. | 8 cm. |
| Trinidad | 6.1 cm. | 10.6 cm. | 8 cm. |
| *Shell thickness*: | | | |
| Colombia | 0.9 cm. | 1.7 cm. | 1.3 cm. |
| Trinidad | 0.8 cm. | 2.4 cm. | 1.4 cm. |
| *Wet cacao weight*: | | | |
| Colombia | 30 gm. | 200 gm. | 110 gm. |
| Trinidad | 50 gm. | 190 gm. | 120 gm. |
| *Number of beans* | | | |
| Colombia | 8 | 38 | 30 |
| Trinidad | 15 | 45 | 35 |
| *Mean wet weight of a single bean*: | | | |
| Colombia | 2.5 gm. | 6 gm. | 4 gm. |
| Trinidad | 1.1 gm. | 5.6 gm. | 3.2 gm. |

Salinas also classified his trees by shape and colour of pod along the lines adopted by Pound (*loc. cit.*). In these qualitative characters the characteristics of the Criollo component came out more strongly than in the qualitative measurements. For example, 80% of the trees fell into the

two pod-shape classes "long point" and "long oval" with the great majority "warty". Thirty-five trees (12%) have "bottleneck". There were 163 trees (58%) with pods more or less red-pigmented and 117 (42%) without red pigment. This proportion is not very different from that found in Trinitario, but the distribution of pigment is entirely different, as 127 trees (45%) had fully pigmented pods. Thus altogether 87% were either fully pigmented or unpigmented and only 13% partially pigmented, whereas in the Trinidad population nearly 60% fall into the partially pigmented classes, and only some 8% are fully pigmented. There is a suggestion here that inheritance of pod colour may be simpler in the Criollo groups than it is in the Trinitario group.

More observations of this kind are urgently needed whilst there are still commercial populations consisting predominantly of Criollo trees.

*Criollos of Doubtful Classification.* There are in the literature scattered references to certain Criollo cacaos about which so little is known that I hesitate equally to classify them definitely in one or other of the groups discussed above or to regard them as constituting a group by themselves. The fragments of information available about them are therefore summarized under this separate heading.

First may be mentioned the wild cacao trees which can be found (though rare) in the forests of Trinidad. These are Criollos, having white or pale cotyledons, and their pods are long, strongly furrowed and warty, with a point as conspicuous as that in the Central American group. Both pods and seeds are rather small, and the pod is very thin-shelled and thin-stalked, frequently with a well-marked "bottleneck". The pod colour may be either yellow or red.

Attention was first called to this cacao by Hart (1909), who called it "Trinidad Criollo" and pointed out the characters in which it differed from the Venezuelan and Nicaraguan Criollos known to him. He described it as "supposed to be indigenous to Trinidad".

The possibility of these Criollo trees being indigenous cannot be entirely ruled out, until our information about the distribution of wild cacaos on the mainland becomes much fuller than it is today; but according to present views it seems a rather remote possibility. They are most unlikely to be recent escapes from cultivation, because they differ markedly from the Trinitario population planted in Trinidad for the last two hundred years, but they are not on that account necessarily indigenous. They seem more likely to be relics of the Criollo stock planted in Trinidad in the seventeenth century, though that view still leaves unexplained the problem of their origin, since there are no authentic records of the first introduction of cacao to the island.

Trees occurring in similar fashion in forests in Tobago bear pods which are partially red on a whitish-green base when young and ripen to a distinctive shade of red. A few old trees of similar type have been shown to me on an estate in Grenada as introductions many years ago from Martinique. Not all these trees have white beans, and they may not be pure Criollos, but some at least segregate white or pale beans and they appear to have affinity with the Trinidad trees. These fragments of evidence point to the former existence of an old cacao population, largely Criollo, which was once widespread in the West Indies and has now practically disappeared.

Van Hall (1932) mentions Criollo trees found in Surinam which appear to be relics of eighteenth century plantations. These trees all have yellow pods, and the one illustrated by Van Hall (*loc. cit.* p. 337) looks rather different from our Trinidad specimens, having a blunter point, high shoulder and no "bottleneck". Cacao is however supposed to have been introduced to Surinam from Trinidad in 1686, and the assumption is that the Surinam wild Criollo and the Trinidad wild Criollo descend from the same stock, which was, no doubt, variable, like nearly every cacao population ever described.

A most interesting point about the "Trinidad Criollo" and the Tobago "highwoods" cacao is the strong resemblance between them and some of the "Criollo de la montagne" observed by Pound in the region round Iquitos and along the Rio Napo and Rio Ortegaza in the upper Amazon system. Pound says of the latter that it is "criollo" only in the literal and not in the botanical sense, and that it produces dark purple beans; but he also states of some of the trees along the Rio Ortegaza that "the pods were distinctly five-sided and contained beans with pale tinted cotyledons". The occurrence of such a cacao at the head of the Amazon system, and relatively near to the South American Criollos of Colombia, is suggestive and highly interesting. The population requires study, and clearly its true affinities should be carefully determined before it is referred to either a Criollo or a Forastero group.

The similarities between "Criollo de la montagne" and wild trees of unknown origin in Trinidad may be accidental, for it is difficult to imagine any early communications between the two districts concerned. But Pound (in a personal communication) points out that although the Rio Ortegaza is an Amazon tributary, the Ortegaza district is also near the headwaters of several Orinoco tributaries. He suggests the possibility that "Criollo de la montagne" forms may have spread down the Orinoco and finally reached Trinidad by that route. This interesting hypothesis could only be supported or disproved by much more information than we have about wild cacaos in the Orinoco basin, but it seems well worth putting on record if only to emphasize the gaps in the data. The distribution of wild cacaos along the Orinoco system bears very closely on the question of the origins of the Trinitario mixture, to be discussed below.

### 7. Amazonian Forastero Cacaos

A wild cacao presenting strong indications of being truly indigenous was discovered by Stahel on the Mamaboen Creek in Surinam (Stahel, 1920) and has been well described and illustrated in Van Hall's textbook (1932). The trees were visited later by Myers (1930) from whose collections living plants were established for study in Trinidad.

Comparison of this cacao with those in the Criollo groups reveals many points of difference, and put alongside, say a Mexican Criollo from the opposite end of the geographical range of cacao, it might well pass for a distinct species of *Theobroma*. It is in fact typical of the forms erroneously referred by Pittier to *Th. leiocarpa* (see below). The pod is whitish green, ripening to a bright clear yellow, oval in outline, with ten clearly marked but not conspicuous furrows and either a rounded end or an extremely blunt point. The seeds are strongly flattened, and the cotyledons dark purple in section.

This cacao is a typical Amelonado in the general usage of the term, but I have avoided that name for the group for reasons that will become apparent. It is easy to see that the Surinam wild cacao is very closely related to the commercial cacaos of Brazil and of West Africa. On the other hand it seems to be only one member of a variable series which occupies the whole of the Amazon basin. The cacao originally introduced to West Africa, either from Surinam or from Brazil, was apparently of narrowly limited provenance, since all observers stress uniformity of appearance as one of the striking characters of the West African Amelonado population. In Brazil itself a little more variation is apparent, and Bondar (1929) recognizes in the main cacao-growing districts three "varieties" called Cacao Comum, Para and Maranhao, distinguished chiefly by slight differences in shape of pod.

Until recently these cacaos seemed to form a group by themselves, but we now have the descriptions given by Pound (1938) to indicate that they represent only one end of a larger series. Higher up the Amazon Pound found very considerable variation in pod characters, yet from observation of such of his introductions as have already fruited in Trinidad there appears no reason to doubt that they all belong to the same group. The main differences are in basal colour of the unripe pod, which varies from dark green to "white", and in pod shape. Some of the types have long warty pods with a pronounced bottleneck and conspicuous point; these externally resemble some Nicaraguan Criollos, but the thickness of the pod wall and the seed characters show their true affinities. The occurrence of this long, warty kind of pod among the Amazon populations is one of several warnings against attempts to classify cacaos on pod shape alone, and against over-eagerness to split the complex into two species. The only fruit characters that all the members of this group seem to have in common are absence of red pigment from the pod wall, and flattish beans with dark purple cotyledons.

Even these may not be entirely constant characters. Absence of red pigmentation from the pod wall is not absolute, because slight traces of pigmentation on the ridges of the pod may sometimes be detected in trees that certainly belong to the Amazonian Forastero group. Also, there is the cacao which Pound calls "criollo de la montagne", occurring in the region round Iquitos and along the Rios Napo and Ortegaza, which sometimes has pods "more than half pigmented" (Pound 1938). "Criollo de la montagne" has been discussed above, where I have made it clear that I am not at present convinced that it is a true member of the Amazonian Forastero series, but it requires study before its affinities are established. Until this point is settled, the occurrence of red pods among the Amazonian Forasteros must be admitted as a possibility.

Nevertheless, for practical purposes, the absence of red pigmentation in the pod can be taken as at least a very common characteristic of Amazonian Forastero populations. Pound says: "Throughout the whole (Amazon) valley the pods were either green or blanco (*i.e.* whitish-green) and only when approaching Colombia was the presence of pigment on the pods encountered". The same applies to Amazonian Forasteros introduced elsewhere. In West African cacao, for example, any red pigmentation of the pod wall (more than perhaps a mere trace on the ridges) can be taken as evidence that the tree which shows it is descended from one of the relatively few Criollos or Trinitarios that have been introduced to the country.

The description of the cotyledons as dark purple is similarly subject to possible exceptions, and to some liberality in interpretation, though the character is sufficiently constant for practical diagnosis. A white-seeded mutation has been described in Brazilian cacao (Miranda and Silva, 1939) and in one important population within the Amazonian Forastero group the cotyledons are described by some authors as pale. This population is the famous Cacao Nacional of Ecuador, which I classify with confidence among Amazonian Forasteros. It has often been described as a distinct and uniform "variety" and so long as we regarded Brazilian Amelonado as a distinct and reasonably uniform variety there was justification for keeping the Ecuador cacao separate. But on the evidence of wide variation along the Amazon the justification disappears and Cacao Nacional takes rank as one of many local populations varying slightly round one main type. It is usually called an Amelonado, though its typical fruit is rather less smooth and more deeply furrowed than typical Amelonado. Among its characteristics are a very large pod, usually with a thick wall, and strikingly large size of tree. The points that give it its high quality rating in the market are apparently that its seeds are much plumper than the general run of Amazonian Forasteros and that the cotyledons are lighter in colour than the average. That such differences

are enough to place the product in an entirely different commercial class from Brazilian or West African Amelonado, does not make them botanically significant, when the sum of all characters is taken into account. Pound (1938) found a cacao very much like the Ecuador Nacional round Yurimaguas on the Rio Huallaga in the Amazon system and suggests that it probably occurs in a long strip from Cuzco northward to Ecuador.

No cacaos of this group appear to have behind them any history of domestication comparable with that of the Central American Criollos. Historical data are inadequate to show exactly when any of them began to be cultivated, but plantations of any considerable extent do not seem to have been made in Ecuador before the nineteenth century, whilst in Brazil cacao seems to have been taken into cultivation from a wild or semi-wild state about 1740.

Since nearly 80% of the world's commercial cacao at the present time is to be referred to the Amazonian Forastero series, the group is of enormous economic importance. Accident has undoubtedly played a major part in determining the particular forms that contribute most to the crop; especially the accident by which a certain kind of Brazilian Amelonado became the foundation of West African plantings. Nevertheless the group has undoubted agricultural merits, and seems to contain a preponderance of vigorous and prolific genotypes. Its limitations lie in the apparent absence of the most desirable combinations of fruitfulness and quality, so that with the exception of the Ecuador Nacional (largely eliminated as a desirable type by its susceptibility to Witches' Broom disease and *Monilia* pod rot) the group includes no "fine" cacaos. Considering that it is only within the last five or six years that the size and variability of the group has become manifest through Pound's investigations, the time is much too early for any assessment of its potentialities as a source of breeding material. The discovery of resistance to Witches' Broom disease among the populations of the Upper Amazon is in itself extremely important. What else of use may be found in these hitherto unstudied populations only time can show. It would seem a reasonable prophecy, however, that cacao breeding programmes of the future will include attempts to combine useful properties from this group with quality from some other cacao group.

### 8. Trinitario Cacaos

The Trinitario group is the most complex of the four, yet in some respects the best known because it happens to have been readily accessible for research in the countries which have the longest records of scientific study in cacao. It has been so much discussed that there is no need for detailed description here, and indeed any concise general description is impossible. The significant characters of it as a population may however be summarized briefly.

Within the total range of variation of Trinitario cacaos it is possible to find individual trees with pods to match externally almost any kind of Criollo or Amazonian Forastero, as well as some types not found in either of those groups. In seed characters there is a similar range of size, shape and colour of cotyledons. Quite extreme variations commonly exist side by side in the same fields, and it is known that the seedling progeny of a single tree may exhibit a range of variation almost as wide as the whole population.

One plausible explanation of this extraordinary variability was first advanced in 1925 by Pittier, who from a study of Trinitario cacaos in Venezuela concluded that they represent a series of forms arising from the hybridization of two distinct groups. Pittiers' nomenclature was unfortunate and his opinion that the parental groups were different species is open to question, but the essential part of his hypothesis has not been shaken by additions to knowledge in the last fifteen years. This hypothesis contributes so much to our understanding of cacao classification that it is desirable to review the evidence in its favour. On the internal evidence alone, that is to say on the range and incidence of variation in the group, it would be possible to support an alternative theory that this is the original, central, variable population from which the other groups of narrower variation have differentiated. We have therefore to see which of the two views can be supported by evidence from history and geographical distribution, and this involves a summary of the slightly complicated history of cacao exchanges between Trinidad and Venezuela.

Trinidad in its earliest days of cacao cultivation (probably dating from about the middle of the sixteenth century) grew a Criollo type, or types, but very little is known about that original population. There seems to be neither any record of its first introduction nor good evidence that cacao of any kind is indigenous to the island. Reference has been made in an earlier section to wild trees occasionally found in Trinidad forests which are assumed to be relics of the old stock in question. If they are indeed such, it is interesting to note that they differ considerably from present day Venezuelan Criollo, suggesting that their origin was elsewhere. And without putting too much weight on the slender evidence from a few surviving trees in forests, it is perhaps worth remembering that apart from geographical propinquity there is no particular reason to suppose that the first cacao in Trinidad came from Venezuela. The whole early history of the crop is so obscure that, for all we know to the contrary, cacao may have been planted in Trinidad some years before it was planted on any considerable scale in Venezuela. The provenance of the trees planted in the two countries may thus have been quite different.

It is a matter of recorded history that in the year 1727 the Trinidad cacao plantations were virtually destroyed by a "blast". The nature

of the "blast" is in dispute, some holding that it was probably a hurricane, though hurricanes are extremely infrequent in Trinidad, and others inclining to the view that it was an epidemic outbreak of disease. According to van Hall, cacao plantations in Jamaica and Martinique were destroyed in the same year. Some thirty years later, the industry was re-established in Trinidad by the introduction of another and hardier kind of cacao, which is the basis of the present population. Again, very few details are available, but in the light of subsequent history there can be little doubt that the new introduction was from Eastern Venezuela, and the likelihood seems to be that it came from the Orinoco, from the district of what is now Ciudad Bolivar. A crucial question is whether it was an Amazonian Forastero, similar to the yellow-podded Amelonado found wild in Surinam, or whether it was already a mixture. No particular name appears to have been given to it in Trinidad.

If it could be proved to have been an unmixed Amazonian Forastero, the logical conclusion would be that the Trinitario mixture originated in the island of Trinidad subsequent to 1756. Van Hall evidently inclines to that supposition when he says (1932, p.383): "Another fact which is equally plain is that after the planting of Forastero trees the same thing happened in Trinidad as in Java and Venezuela, namely, a pollination of the newly planted Forastero trees with pollen of the old Criollo. The result has been an offspring of hybrids which show a combination of Forastero and Criollo characters, and this hybrid character is still quite apparent in the trees to be found on the Trinidad cacao plantations at the present day". Van Hall is evidently interpreting "Forastero" to mean what I have called "Amazonian Forastero", because on the same page he speaks of "the pure Forastero cacao as found in Surinam, East Venezuela, and the African cacao countries". But this begs the question whether "pure Forastero" as found in Surinam and the African cacao countries *does* occur in Eastern Venezuela, and illustrates the confusion always caused by the unfortunate word "Forastero" whenever it is used without qualification.

Certainly the planting of the new cacao in the remnants of old Criollo fields in Trinidad must have created ideal conditions for extensive hybridization, and we may reasonably assume that the present complexity of the Trinitario population was largely attained in that phase of its history. But we have to admit the possibility that some mingling had already taken place on the mainland before 1756, and to my mind such mingling is very probable.

All the subsequent confusion in nomenclature arose from the fact that about 70 years later the same cacao either—in its original form or somewhat altered by its association for a generation or two with Criollo types in Trinidad—was *sent back* to Venezuela. It was sent, however, not to the district from which it is believed to have originated, but to the main cacao growing districts in the central part of the coast (around, and west of, La Guayra). Here it was not recognized as a Venezuelan cacao, and the terms "Forastero" and "Trinitario" came into use to distinguish it from the Criollo which was the only kind known up to that time. Thus Perez Arbelaez (1937, p.82) says that "Forastero came to Venezuela in 1825 from Trinidad" and that it was called by the older writers "cacao of the islands".

It may at first seem strange that the Venezuelan planters should not have recognized a Venezuelan cacao that had only been out of the country about seventy years, but on reflection it is readily understandable. On account of the lie of the land direct communications between the main cacao-growing region and the plantations in the Orinoco basin must have been almost non-existent, whereas communications of both with Trinidad, by water, were easy. Thus there is every reason to believe that until some time in the nineteenth century the plantations of Venezuela in general, excluding those of the Paria peninsula and along the Orinoco, consisted only of the old Criollo forms. A natural corollary is the conclusion that outside Trinidad itself the Trinitario mixture was until then confined, at its widest, to the excepted regions— the Paria peninsula and the plantations along the Orinoco.

Subsequent to the introduction of the Trinitario further west, the history has been one of gradual diminution in the proportion of pure Criollo trees in the plantations, reflected in gradual decline of the quality of the product. The reason always given is the much hardier constitution of the invading population, and this is a fact obvious to anybody who has ever seen a mixed field of Criollo and Trinitario trees.

If then, we are to regard the Trinitario as an original heterogeneous population from which the South American Criollos on the one hand and the Amazonian Forasteros on the other have differentiated, we encounter the difficulty that until a little more than a century ago its distribution was apparently very limited; and not only limited but rather sharply discontinuous from the distribution of its supposed offshoots with one of which at least (the South American Criollo group) it competes on much better than equal terms whenever the two populations are brought together by man. To my mind such a state of affairs is incredible, and thus the balance of the evidence, incomplete as it is, heavily favours the view that Trinitario is a mixture of recent origin.

The weakest point in the evidence is our lack of knowledge about wild cacaos in the upper Orinoco basin, which lies between the known distributions of the South American Criollo and Amazonian Forastero groups. But in any case, even if further investigation should disclose a wild population with Trinitario characteristics, indicating a wider and older distribution of the group than is now apparent, it would remain true

that plantation Trinitarios have developed much of their complexity in historical times and by the acts of man.

We may conveniently describe Trinitario as a group of mixtures rather than as one mixture because material either from Trinidad or from Venezuela has been widely distributed in the cacao-growing countries of the whole world, and wherever it has gone the original mixture has become more complex and is at present still evolving. Naturally when introductions have been made from one country to another they have not included the whole range of variation represented in the parent country: but the introduced material has been planted among an older population, usually of Criollo ancestry, and has proceeded to hybridize with it. In consequence, the mixed cacao of Ceylon is not identical in its composition with the mixed cacao of Trinidad from which it stems. The mixture in Java, though of similar origins, probably differs in some respects from the mixture in Ceylon. In Ecuador mixing is taking place between introduced Trinitario forms and the Cacao Nacional, whilst in Southern Mexico and the Central American countries the Central American Criollos are involved. It is convenient to have one inclusive term for all these hybrid populations, and as Trinitario in the literal sense is nearly always one of their constituents, its name may usefully be extended to cover all cacaos having a blend of Criollo and non-Criollo genes.

At the present time Trinitario cacaos form about 20% or less of the world's cacao crop, but we may confidently forecast a progressive increase and it seems likely that a century hence selections from the present day mixtures or new hybrids of similar parentage may be the only cacao grown on any considerable scale. Each of the other groups, though very variable, has its easily recognizable limitations, and the limitations are largely complementary; thus for the building up of more profitable genotypes inter-group hybridization opens up possibilities of almost unlimited scope. No systematic attempt has ever yet been made to exploit the full range of variation in the main Criollo and Amazonian Forastero groups, and when they have been more thoroughly surveyed there is no doubt that the plant breeder working on cacao will have a wealth of material to his hand. Meanwhile, the Trinitario mixtures as they are serve to indicate the possibilities both good and bad. They show that individual trees can be produced from Criollo-Forastero crosses to combine hardiness and quality to a remarkable extent. They also show that segregation from such crosses gives a population of but mediocre average performance, and including a large proportion of worthless trees, so that mingling of the groups without careful selection and vegetative propagation may be positively detrimental. The Trinitarios therefore will repay study for the sake of the guidance that can be obtained for cacao-breeding programmes, as well as for the sake of the excellent genotypes that can be selected from them.

### 9. Possible Origins and Relationships

We have now seen that, although the wild and cultivated cacaos form one interbreeding population, nevertheless the "original" cacaos of Central and South America fall into two rather well-marked divisions—the Criollos and the Amazonian Forasteros. The Trinitarios, with their intermediate characters, tend to obscure the division, but if they are regarded as owing their intermediate position very largely (if not entirely) to relatively recent hybridization, they may be set aside for simplification of the picture.

Two questions now arise, which it should be among the aims of cacao research to answer because they are bound up with the genetics and hence with the improvement of the crop. One is, when and how the existing divergence between Criollo and Amazonian Forastero took place; the other, whether that divergence is wide enough to warrant the recognition of more than one botanical species among cultivated cacaos.

The first step is to determine the centre of common origin of Criollo and Forastero cacaos; for a common origin they must have had, however far back in time they diverged. This centre is more likely to have been in South America than in Central America, because both still occur there, whereas nothing is known of any indigenous Forastero type beyond the Panama Isthmus. It must have been in a region from which two or more lines could diverge geographically as well as botanically, and according to the Vavilov principle it should be the region where the greatest variation is shown today among indigenous cacaos.

Pounds' account of his necessarily limited explorations in 1938 suggests very strongly that he reached such a centre, or at least approached it closely, in the region round the upper waters of the Rios Napo, Putumayo and Caqueta, tributaries of the Amazon which all arise in the Andes near the Equator. Here, within an area that could be circumscribed by a circle of 250 miles radius, there occur (a) what Pound calls the Amazon population within which he recognizes several sub-populations differing mainly in pod characters (b) cacao apparently identical with the Nacional of Ecuador (c) a population called "Criollo de la montagne" which, though not botanically a pure Criollo, includes some trees with pale-tinted beans. From Pound's descriptions, almost every known type of pod shape can be found in this area, and also both unpigmented and "more than half pigmented" pods. A slight extension of the radius of the circle would bring in the South American Criollos of Colombia, occurring just to the north of the region defined, but on the other side of the Cordillera.

The various kinds are not growing side by side as one mixture. On the contrary, Pound describes for each of the rivers up which he travelled one more or less distinct central type, with variations linking it up with the central types of other districts.

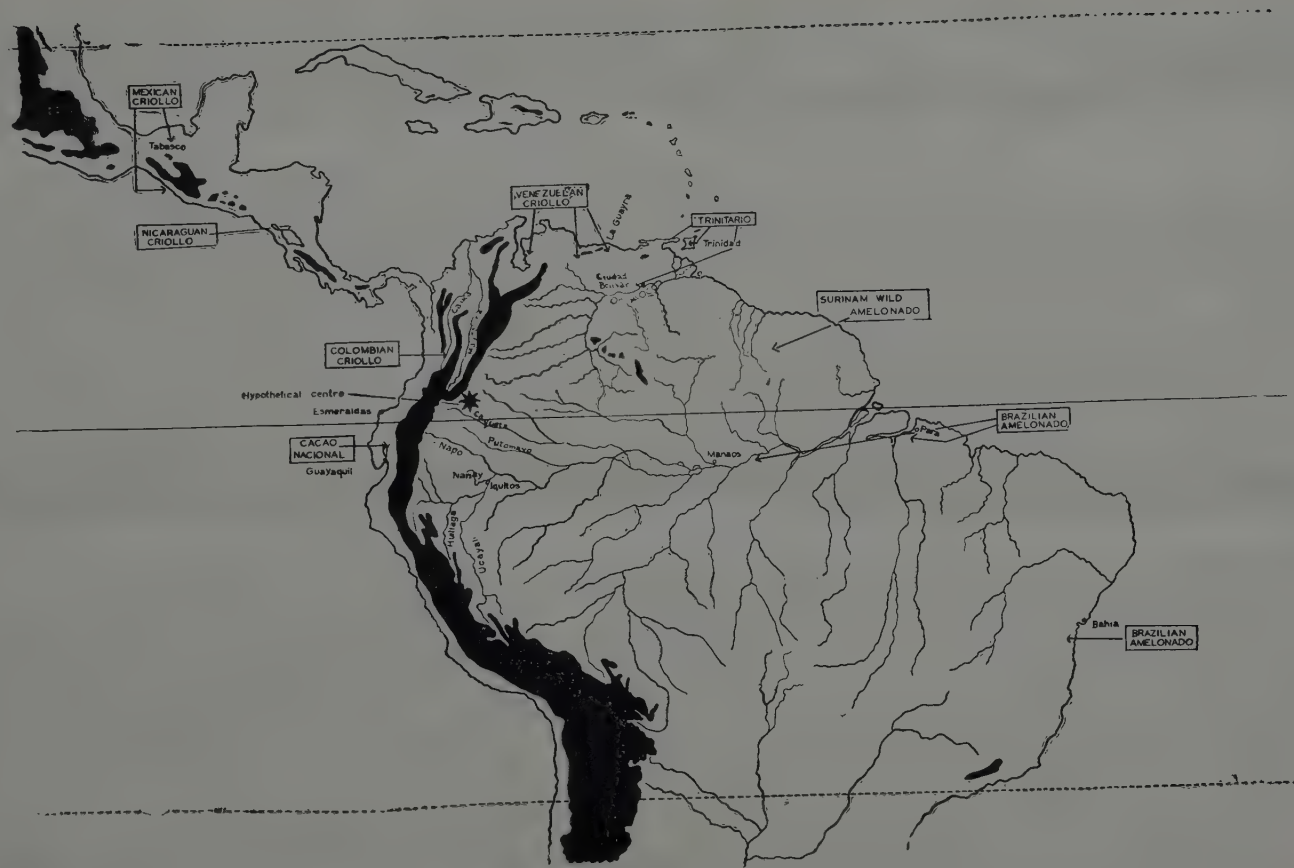



Fig. I. Map of the area in which cacao is cultivated or indigenous in the New World. Land above 6,000 ft. shaded in black. Hypothetical centre of origin shown by star just north of the Equator.

Such differentiation of local sub-populations, even at the centre of origin, is exactly what we should expect, having regard to the topography of the country concerned. It therefore seems significant that within so small a compass there should occur a range of variation from which it is possible to imagine the derivation of almost any type of cacao known elsewhere.

Many gaps remain in the data, and in particular we need to know more exactly the southern and eastern limits of distribution of true Criollo cacaos. There is also a puzzling discontinuity in the distribution of red-podded types so far recorded which can only be explained by further observations in the field. From the frequency of fully pigmented pods among South American Criollos and their occurrence to a lesser extent in Central America we should expect to find wild trees with fully red pods somewhere in the region of common origin, but they do not appear to have been found. In fact there appears to be no record anywhere of an indigenous cacao showing the combination of full red colour with Amelonado or Calabacillo pod shape and dark purple cotyledons, though it is a combination quite common among Trinitarios. We have to assume at present that all the red pod pigmentation in Trinitario comes from the Criollo component in their make-up, but the assumption is not altogether satisfying. Discovery of a wild and indigenous "Red Amelonado" anywhere in the Orinoco basin would modify to some extent our views of the origins of Trinitario mixtures, which may well be even more complex than Pittier's hypothesis suggests.

With all due allowance for these imperfections, the theory that the cacaos originated in or near the region specified seems very plausible. But to frame any satisfactory hypothesis about the course of their subsequent spread and differentiation is much more difficult.

The map (fig. 1) suggests no natural barrier to dispersal to the north-east, east or south-east, and we may suppose that in fact cacao spread in those directions by natural means. This assumption fits the observed reduction in variation eastward along the main Amazon stream, in which direction it is clear that only yellow-podded, dark-beaned types moved. Presumably similar types will be found in the southern half of the Amazon basin, but no data are yet available from that vast region. With regard to the spread to the north-east, and into the Orinoco basin, we are similarly without data, and in this case we cannot assume that the same types moved; quite possibly a mixture of red-podded and yellow-podded forms, or even red-podded alone may have travelled that way, to contribute to the Trinitario mixture of north-eastern Venezuela.

To the north and west of our hypothetical centre there is a formidable barrier to natural dispersal, in the form of the Cordilleras, and it cannot be without significance that the eastern Cordillera with its north-eastern extension also marks exactly the boundary between the known distributions of Criollo and Forastero cacaos a little more than a century ago. A possible argument from this fact would be that the two groups had separate origins and were prevented by the mountain barrier from mingling, but the botanical evidence of close relationship is too strong for that theory to be accepted. In particular, the view that Criollos originated in Central America and spread south-eastward seems to me hardly tenable since the evidence though admittedly imperfect, tends to show that variability in the Criollos falls off from Colombia through Central America to Mexico, and not in the reverse direction. I therefore prefer the hypothesis that a small section of the original population on the eastern side somehow crossed the Cordillera at an early time, and that from it evolved the two Criollo groups as we know them today. On this view the Cordillera was the barrier permitting differentiation of the well-marked characters of all Criollos, and the isthmus of Panama acted as a secondary barrier permitting further differentiation of a distinct Central American population out of the limited amount of material that crossed it in a westerly direction.

The manner in which the original stock crossed the high mountain chain can only be guessed at, but we may consider the possibility that man was involved. It is at least a striking coincidence that in the only region where we have definite evidence of human interest in cacao from early times (viz. in Mexico) we find a high quality cacao, and one is tempted to see in the fact the possibility of something more than a coincidence. To begin with, the species has no specialized mechanism for natural dispersal of its seeds, which are probably distributed in nature by monkeys and smaller mammals; and its rate of spread must be severely restricted by the fact that the seeds quickly lose viability when removed from the pod. Therefore man is the only agent that can be readily thought of for the transport of seeds over so formidable a barrier as the Andean mountains. But if man did transport the species, and had sufficient interest in it to do so, nothing would be more natural than that he should choose the types with the palest cotyledons and the plumpest seeds, having by experience found those the least bitter and most desirable. After its initial transit of the mountains the species may have spread naturally again for a time until it reached Central America, where further human influence completed the evolution of the Central American Criollos.

The objection to this hypothesis is that it is unsupported by historical data, which provide no evidence for early cultivation of cacao in the Andean region of South America. Indeed, Mangelsdorf and Reeves (1939) have cited cacao as an outstanding example of a useful plant well known to the Aztecs and Mayas but apparently completely unknown to Peru before the Conquest. That side of the question must be given due weight, but negative evidence does not conflict seriously with the hypothesis stated. We must accept that the civilized tribes of the Andean region never learned to use cacao as the Aztecs used it, and consequently never valued it to any similar extent. But it is not necessary to suppose that they did not even know it as a plant which had a pleasant

edible pulp around its seeds. Any primitive use of the plant might have been sufficient incentive for the limited amount of transport necessary to our hypothesis, though it must be admitted that if the seeds were used only for their pulp there would be no point in the selection suggested. Perhaps, after all, the original divergence of the Criollo stock was purely accidental; and where everything is so obscure we can only speculate in an attempt to find some clue to events.

As a minor complication of the problem, it seems necessary to postulate *two* independent crossings of the Andes, the second being that which gave rise to the "Cacao Nacional" population of Western Ecuador. The latter was apparently carried over from a point some distance south of the centre of variation, and therefore developed as a fairly uniform type. There is some evidence for subsequent mingling of the Nacional type from the south with a Criollo from the north in the region of Esmeraldas on the Pacific side.

Accepting for the sake of argument that the South American Criollos originated from a cacao carried over the Cordillera into the headwater region of the Magdalena and Cauca Rivers, we can see from the map how by way of the valleys of those rivers and the Caribbean coast they might ultimately reach the central Orinoco basin and there come into contact with another stock, spreading from the same original centre along the eastern side of the Cordillera. This consideration provides us with one possible origin of the Trinitario group of cacaos, and pending further information from the upper Orinoco such an origin appears as likely as any other.

The chief value of the map, however, is probably to show how vast is the area yet to be explored before we can claim to have even a fair knowledge of the distribution of wild cacaos. Therefore the attempt to produce a working hypothesis from the fragments of evidence available must not be misinterpreted as a rash leap to conclusions.

### 10. The Species Question

Leaving open the question of when and how the Criollo and Amazonian Forastero cacaos diverged, we have next to consider the question whether their divergence is sufficiently wide to warrant the recognition of more than one botanical species among cultivated cacaos today. If there are two species of *Theobroma* concerned, it is unquestionable that the division between them is identical with that between these two main groups, and it has been pointed out above that if comparison were limited to types from extreme ends of the cacao range (Mexican Criollo and Brazilian Amelonado) these might well pass as representatives of distinct species, on morphological and physiological grounds alone.

When we take into account all known cacaos, however, both morphological and physiological differences become much less well marked, and we find that parallel variation occurs in almost all the field characters (such as the taxonomist ordinarily uses) in both groups. It then becomes apparent that for the decision of the species question we need *genetical* evidence, which we have not got and may not get for some years.

The characters that enable us to make a field diagnosis between the groups have been given in earlier sections, but may for convenience be recapitulated here:

*Criollo* cacaos have pods either red or yellow in colour when ripe, usually deeply ten furrowed, very warty and conspicuously pointed; the fruit wall is relatively thin and easy to cut; the seeds are plump and the fresh cotyledons white or pale violet in colour. *Amazonian Forasteros* have pods nearly always yellow in colour when ripe, usually much less deeply and often inconspicuously furrowed, often smooth, sometimes more or less warty, and commonly round-ended or bluntly pointed; the fruit wall is relatively thick and often has a woody layer difficult to cut; the seeds are more or less flattened and the fresh cotyledons dark purple in colour.

Such descriptive phrases, coupled with observations that the Forastero cacaos as a class are much more vigorous than the Criollos, and often broader-leaved, give a sufficiently clear concept of the groups for many practical purposes, and such unusual forms as smooth-fruited Criollos or plump-seeded Forasteros can be referred to their right class without difficulty on the sum of their characters. Yet it is noticeable that all the pod characters have to be qualified by expressions such as "often", "usually" or "relatively". The seed characters are better, but involve personal judgment in decision between light purple and dark purple and between plumpness and flatness.

When we try to go beyond pod shape and look for distinguishing characters in the flowers or leaves, or in the general habit, we can find nothing more definite—on the contrary, though differences occur from tree to tree which may be useful in helping to distinguish clones, the total range of variation in floral characters is astonishingly small, and I have never been able to find any characters to distinguish the flowers of Criollo trees in general from those of Forastero trees in general. The physiological differences are useless, partly because they are difficult to measure, and still more because we do not know to what extent they are constant.

It is interesting to observe that all the diagnostic characters concern the part of the plant useful to man, with the seed characters considerably more constant than the external fruit characters. This may or may not be significant, but it certainly detracts from the value of the characters as indicators of specific difference, since the probability of human influence on the divergence of the groups is too great to be ignored.

In these circumstances, only genetical reasearch can enable us to assess the true position. Divergence has certainly not gone far enough to prevent the sections from interbreeding, but it has possibly gone far enough to impair to some extent the fertility of crossbred progenies. The common incidence of so-called "self-incompatibility" in Trinitario cacaos (which seems in this case to be

essentially a manifestation of partial sterility) is one pointer to the possibility of slight disharmony between the genetic elements in their make-up. On the other hand, the very heterogeneity of the Trinitario group shows that any such disharmony must be very slight; with any considerable disturbance of fertility we should except more discontinuity in the variation. What is now needed is a careful study of controlled crosses between cacaos of different groups, especially those which appear to have evolved in comparative isolation, to determine how far their genotypes differ in essentials. Meanwhile, there can be no advantage from the point of view of convenience in recognizing two or more species which cannot even be satisfactorily defined.

### 11. Specific Nomenclature

The Latin name usually given to all cacaos is *Theobroma Cacao* L., and so long as we accept that they all belong to one species, that as the oldest binomial is undoubtedly valid. There are, however, two other binomials in fairly common use, viz. *Th. pentagona* Bern. and *Th. leiocarpa* Bern. I think that both of these should be rejected, irrespective of whether *Theobroma Cacao* should or should not be divided, because neither applies to anything more than a form of Central American Criollo cacao.

*Th. pentagona* Bern. is used for the so-called "Alligator cacao" or "Cacao Lagarto" of Mexico and Central America. The fruit of this, illustrated by Bernoulli in compiling his original description (Bernoulli 1896) and later by Preuss (1901) has characters as well-marked as can be desired to distinguish it from the bulk of the population in which it occurs, and it appears to have no parallel among other groups of cacao. If ease of recognition were the criterion of a good species, *Th. pentagona* would undoubtedly be one. Yet apart from its highly characteristic fruit it has no distinguishing characters that I can find,* and pod shape is notoriously the most variable character throughout the cacaos. Thus we have to do with one form of a variable species, which in one of the most variable characters happens to depart a little further than other forms from the norm. By itself the morphological evidence certainly does not justify specific rank for *Th. pentagona*.

Some idea of the probable status of alligator cacao can be gathered from its distribution. In Mexico it occurs as scattered trees in Criollo plantations, never very frequent but usually represented by a few individuals and Preuss records a similar distribution in Nicaragua, Salvador and Guatemala.†

We know that it crosses readily with the Central American Criollo, as with other cacaos, and we have no knowledge of it in a wild state. Its behaviour therefore suggests that the peculiar fruit shape depends upon a particular combination of relatively few genes, and that in the seedling progenies of a largely cross-fertilized population this particular combination segregates out according to accepted Mendelian laws. There is no reason to suppose that the genes controlling fruit shape are necessarily important ones in the general make-up of the species, and if they are not then the category of "forma" would seem more appropriate for alligator cacao than even "varietas", and "species" is out of the question. Fortunately the status of *Theobroma pentagona* is a question that can be answered by genetical researches, and the hypothesis here advanced will in due course be tested, but the evidence available at present certainly does not justify the use of a specific binomial for this form of cacao.

*Th. leiocarpa* Bern. was originally used (Bernoulli 1869) for a cacao in cultivation on the Costa Grande of Guatemala. Bernoulli's description of it is almost word for word the same as his description of *Th. Cacao* until it reaches the fruit, when the following differences occur.

*Th. Cacao* L. . . . . *fructu glabro coriaceo-cartilagineo, ovato-oblongo, apice sensim attenuata, decemsulcato, jugis inter sulcos irregulariter rugoso-tuberculatis; seminibus ovatis.*

*Th. leiocarpa . . . . . fructu coriaceo-cartilagineo, ovato, obsolete quinquesulcato, laevi; seminibus ovatis.*

The description is supplemented by an illustration showing a smooth pod, with only five furrows, narrowing rather gradually to a blunt point. It is important to observe that no differences are noted between the seeds of *Th. leiocarpa* and those of the *Th. Cacao* trees among which it is found. On the contrary, Bernoulli says that the seeds are very similar, and are not kept separate when harvested. He adds that *Theobroma leiocarpa* occurs scattered in the cacao plantations of Guatemala and is rarer than *Th. pentagona*.

Preuss, writing thirty years later, says that he saw *Th. leiocarpa* on the Costa Grande and could not accept it as a distinct species. "It resembles in externals the Calabacillo of Trinidad and the Cojon de toro of Venezuela. The beans, however, are entirely different from those of Calabacillo".

On this evidence, the most reasonable hypothesis to be held about this "species" is the same as that advanced above to explain the origin and relationships of *Th. pentagona*. It is most probably a genotype ("forma" rather than "varietas") which segregates occasionally in seedling populations of Central American Criollo by the recombination of certain genes controlling pod shape. As in the case of *Th. pentagona*, the hypothesis can only be proved or disproved by genetical research, but in its favour may be mentioned what appears to be a parallel case in another Criollo cacao. Van Hall (1932, p.85,) has described and illustrated a variety of Java Criollo (which is Venezuelan in origin) called Porcelaine, of which he says: "The

*Bernoulli says "*differt floribus fere duplo minoribus et praecipue fructu distinctissimo*", but I cannot confirm his observation about flower size. This is another variable character, and it is most unlikely that he examined a range of specimens.

†"An Anzahl der Baume is der Lagarto am wenigsten vetreten. Bestande ausschliesslich von dieser Art, selbst nur kleine, habe ich nie gesehen, leider auch nie eine Quantitat von Bohnen nur von Lagarto" (Preuss, 1901, p. 263.)

smooth surface and the lack of prominence of the ridges give it a strong resemblance to the Amelonado, a Forastero sub-variety, but the thin fruit wall and the rather plump seeds show that it is really a Criollo. This is also proved by the fact that it was found in the Criollo plantations in Java before the introduction of the Forastero . . . . . In twenty fruits Zehnter found 68 per cent. of round beans. Further, all the seeds were white—another Criollo characteristic, . . . . It is probable that it has suddenly appeared as a variety (a so-called "mutation") of true Criollo parents, among many sisters which were true Criollo like their parents".

Whatever its exact origin there can be no doubt from the original description that *Th. leiocarpa* Bern. belongs to the Criollo division of cacaos. This point is very important, because the name has been misapplied, and increasingly used in recent years to distinguish the class of cacao which forms the bulk of the crop in Brazil and West Africa and which is found wild and apparently indigenous in Surinam. The latter belongs definitely to the Amazonian Forastero division, and whatever it is to be called it cannot validly be called *Th. leiocarpa*.

The misuse of this binomial is primarily due to Pittier (1925) who, in drawing attention to the hybrid nature of the Trinitario cacao of Venezuela, chose to restrict the name *Th. Cacao* L. to the Venezuelan Criollo which is one of the putative parents of the Trinitario and selected Bernoulli's combination for the other putative parent. The name *leiocarpa* happens to suit very well the smooth-fruited "Amelonado" type in question, and that circumstance may have influenced the present writer in accepting Pittier's nomenclature (tentatively in 1932 and more definitely in 1938) without a sufficiently critical scrutiny. There is, however, no valid excuse, and for the extent to which I may be responsible for West African cacao being referred to *Th. leiocarpa* I can only apologize. Actually, the Brazilian and West African Amelonados have nothing in common with *Th. leiocarpa* except the smoothness of the fruit, as Bernoulli's illustration demonstrates quite clearly. If the Amazonian Forasteros are to be given a specific name to themselves there is probably one available among the numerous synonyms of *Th. Cacao*; but it must be selected carefully in accordance with the rules of nomenclature, and would have to be the oldest validly published binomial that can be shown to have been applied originally to an Amazonian Forastero tree. The selection would therefore require careful nomenclatural research for which conditions at the present moment are not favourable.

## 12. Summary

The cultivated, semi-wild and wild cacaos form one inter-breeding population, within which it is not necessary at present to recognize more than one botanical species. Judged on the morphological characters ordinarily used by taxonomists, the differences between the component local populations are no more than might be expected in a variable, cross-fertilized species part of which has been subjected to some centuries of human influence as a crop.

The specific names *Theobroma pentagona* Bern. and *Th. leiocarpa* Bern. apply to certain forms which, though strikingly different in fruit shape from the bulk of the local population in which they occur, do not merit specific rank. All cacaos, therefore, may for the present be referred to *Th. Cacao* L.

The traditional division of all cacaos into Criollo and Forastero is a sound and natural one, after allowance has been made for a large class of hybrids, which otherwise obscure the line of division.

The term "Forastero" however, was originally applied to a population now believed to be largely hybrid in origin, and was only later extended to cover all cacaos that are not Criollo. It is therefore necessary to re-define it, making clear that it covers (a) Amazonian Forasteros, which have evolved in comparative isolation and (b) hybrid populations which contain Criollo elements and are better distinguished as Trinitarios.

The Criollo are the "original" cacaos of Colombia, Venezuela and all Central American countries to southern Mexico. They occur wild in some of these countries, but as they have been cultivated for a long time (probably several thousand years in Mexico) it is an open question whether they are indigenous in any Central American country. They may have originated from an offshoot of a general cacao stock in the headwaters of the Amazon, carried over the Andes into southern Colombia, and developed many of their present characters in association with man. Their product is of high quality, which may be accidental but suggests possible human influence from an early stage of their evolution. Criollos may be subdivided geographically, the Central American population presenting a rather different facies from the South American, and being further divisible into local populations such as Mexican Criollo, Nicaraguan Criollo and so on. The South American group appears to exhibit a greater tree to tree variation, consistent with a position nearer the centre of origin, but neither Criollo group is well known. Unfortunately, studies of variation in both, though badly needed, are complicated by the extent to which both have become contaminated by introduced Trinitarios in recent years.

The Amazonian Forasteros occur wild and semi-wild along the main Amazon river and its headwater tributaries, and also west of the Andes in Ecuador. Before the investigations of Pound (1938) practically nothing was known about this group as a whole, and even now its distribution is imperfectly known, as the whole southern half of the Amazon basin and most of the Orinoco basin have still to be investigated for wild cacaos. No cacao of this group has any history of ancient cultivation, but two of its constituent populations, from opposite ends of the range, have played important parts in recent cacao cultivation. One of these is the Cacao Nacional of Ecuador the past history of which is obscure and the other is Brazilian

cacao, which appears to have been taken into cultivation from a semi-wild condition only two hundred years ago. Ecuador was first among cacao-growing countries for many years until supplanted by the Gold Coast growing a Forastero of Brazilian origin. These two are relatively uniform populations, but in the group as a whole there is considerable variation, of which the full range remains to be explored. Two characteristics of the group are noteworthy, namely vigour and productivity, which enable Amazonian Forasteros to bear crops in some environments where Criollo will not thrive.

The Trinitarios are highly heterogeneous populations, not known in the wild state. The best known of them is the cacao population of Trinidad, material from which has been introduced in the nineteenth and twentieth centuries into most cacao-growing countries of the world. The origin of this group is presumptively a mingling of South American Criollo and Amazonian Forastero stocks, which is most likely to have taken place in plantations in the lower Orinoco basin. Such origin may have been complicated by inclusion of other elements (not yet described) from the upper Orinoco. In any case, modern Trinitarios certainly contain both Criollo and Forastero genes. The outstanding characteristic of the group is its extreme variability from tree to tree, the total range of variation being very wide indeed. The best individuals in the mixture combine the vigour of the Amazonian Forasteros with much of the quality of the Criollos, and there is little doubt that by selection clones can be established of greater all-round practical utility than any of the "pure" cacaos. On the other hand, many individuals in the mixture are commercially undesirable or even worthless. A large proportion are self-sterile, and this and other manifestations of partial sterility may prove to be consequences of the hybrid constitution.

The various pod shapes in the Trinitario mixtures may for convenience be grouped under the old names Angoleta, Cundeamor, Amelonado and Calabacillo, but these names should never be regarded as standing for "varieties". There are no true or definable varieties within the Trinitario group, because the variation within any local population and between local populations is continuous. The only definable unit is the clone.

**Acknowledgment**

I am deeply indebted to Dr. F. J. Pound and Mr. J. B. Hutchinson, for much helpful discussion during the preparation of these notes.

**Literature**

Bondar, G. (1929). O cacao (2nd ed.) Bahia.

Cheesman, E. E. (1932). The economic botany of cacao. *Suppl. Trop. Agriculture*, Vol. 9, June, 1932.

Cheesman, E. E. (1938). Recent botanical researches in cacao. *Empire J. Expt. Agric.*, 6. pp. 219-24.

Hart, J. H. (1909). The characters of Criollo cacao. *W. Ind. Bull.* 9, pp. 161-162.

Mangelsdorf, P. C. and R. G. Reeves (1939). The origin of Indian corn and its relatives. *Texas Agric. Expt. Stn. Bull.* 574.

Miranda, S. and P. Silva (1939). Mutacoes em *Theobroma leiocarpa* Bern. var. Comum. *A Bahia Rural* Oct.-Nov. 1939.

Myers, J. G. (1930). Notes on wild cacao in Surinam and in British Guiana. *Kew Bull.* 1930 pp. 1-10.

Perez Arbelaez, E. (1937). Manual del cacaotero Venezolano. Caracas.

Pittier, H. (1925). L'origine hybride des cacaoyers cultivés. *Rev. Bot. Appl.* 5. 908.

Pound, F. J. (1932). The genetic constitution of the cacao crop. *First Ann. Rept. Cacao Res.* 1931. pp. 10-24. I.C.T.A.

Pound, F. J. (1933). The genetic constitution of the cacao crop. *Second Ann. Rept. Cacao Res.* 1932. pp. 9-26. I.C.T.A.

Pound, F. J. (1938). Cacao and witchbroom disease of South America. Port-of-Spain, Trinidad.

Preuss, P. (1901). Expedition nach Central-und Sudamerika. Berlin.

Stahel, G. (1920). Een wild Cacaobosch aan de Mamaboen Kreek. *Die Indische Mercuur* 43e Jahrg. no. 39. pp. 681-2.

Van Hall, C. J. J. (1932). Cacao (2nd ed.) Macmillan, London.

## WEED CONTROL IN LOUISIANA

According to an article by E. M. Summers *et al* in *Sugar Bulletin*, Vol. 22, No. 4, pp.29-30 it has been demonstrated that mule-drawn flame cultivators can give adequate weed control without injury to sugar cane. A standardized unit is now being produced commercially and a number of these may be in operation next season. The "Burden system" of two years of summer fallow with a winter legume smother crop during the intervening winter has been widely adopted for the control of Johnson grass, *Sorghum halepense*, and has proved quite effective. While it does not always eliminate the Johnson grass entirely, this practice does control it sufficiently to largely restore the land to normal productivity. The two years of summer fallow frequently results in increased yields as compared with non-infested fields in the regular rotation. This compensates partially for the loss of use of the land for an extra year between cane plantings. It is believed that farms badly infested with Johnson grass can afford to devote upwards of 10 per cent. of their acreage to this type of control. The use of this system for the control of alligator weed, *Alternanthera philoxeroides*, has shown some promise but has been less effective than with Johnson grass. Shading by a vigorous growth of legumes or a variety of cane that produces early dense shade seems to have more promise for the control of alligator weed, which is unable to compete with such plants for sunlight because of its prostrate growth habit. Ditch-bank weeds continue to be one of the greatest problems. Some growers have been using densely growing varieties of cane in such places. The use of weed-killing chemicals on ditch banks has not given good results.—(*Sugar*, 39, No. 4, p. 45, 1944.)

## CHEMICAL NOTES

*(Compiled by the College Department of Chemistry and Soil Science)*

### Zinc Deficiency in Pineapples

According to experiments carried out by the Hawaii Agricultural Experiment Station (*Rept.*, 1942) a relationship has been found between the degree of zinc deficiency exhibited by pineapple plants and the available zinc in the soil. Apparently, the abnormalities of pineapple plants that can be cured by spraying with zinc sulphate result directly from the inability of the soil to supply sufficient zinc to the plant. Zinc in the plant was found in greatest amounts in the meristematic tissues, and its concentration there formed the only critical index related to the deficiency symptoms.

* * *

### Paper and Cellulose Possibilities in West Africa

The possibilities of certain West African grasses as a source of material for the local manufacture of paper and cellulose are discussed by J. N. Oliphant in *Farm and Forest*, 4, 39-41. The grasses in question are elephant grass (*Penisetum purpureum*) from Southern and gamba grass (*Andropogon gayanus*) from Northern Nigeria, both of which secured fairly favourable opinions on examination by the Imperial Institute, and *Vossia cuspidata*, a semi-aquatic grass of Lagos and of the sudd of the Upper Nile. This has not been tested. It might be harvested by detaching islands by means of an underwater saw and towing them to a factory.

* * *

### Potash Fixation

L. K. Wood and E. E. De Turk studied the potash equilibrium in soils stored in the laboratory after moistening with potassium chloride or potassium phosphate solution. Three forms of potassium were determined—"replaceable", "acid-soluble" and "acid-insoluble". These three forms were found to be in a slowly shifting equilibrium, obeying the law of mass action. Previous treatment in the field with potash or other fertilizers had little effect on the equilibrium. The amounts of native replaceable and acid-soluble potassium were largest in young, and smallest in old, soils. The fact that potash-fixation is an equilibrium effect suggests that in some soils, fixation is not necessarily agriculturally undesirable. It reduces wastage by leaching and adds to the reserves of colloidally-bound potash in the soil that are recoverable in a few weeks.

A. S. Ayres showed that the amount of potash absorbed by soil from a salt solution increased with the concentration of the solution. The application of small amounts of potassium through the medium of irrigation water may therefore result in undue losses of the nutrient. The presence in the soil complex of other exchangeable bases also increased absorption of potash. W. E. Worsham, and M. B. Sturgis studied 14 soil-types of the Mississippi Delta region and found that, in general, high available potash was associated with a high base-exchange capacity, except in soils completely base-saturated. Addition of calcium salts and organic matter and saturation with water markedly increased potash availability.—(*Imp. Bur. Soil. Sci., Soils and Fertilizers*, 1943, Vol. VI, No. 3, p. 108.

* * *

### Poisoning from Bamboo Shoots

According to a report issued by the Bengal Government Chemical Examiner, cases of fatal poisoning in men and cattle who have eaten shoots of the ordinary bamboo (*Bambusa arundinacea*) have been recorded in Bengal. The determination of the exact nature of the poison contained therein has so far baffled the toxicologists. This investigation was taken up at the beginning of 1941 and it was found that the shoots (when 6 to 18 inches in height) contain varying amounts of a cyanogenetic glucoside which on hydrolysis yields hydrocyanic acid, glucose and parahydroxymandelic acid. In one shoot, as much as 0.8 per cent. of HCN was obtained. About 2 ounces of such a shoot are enough to kill a healthy man. The maximum of HCN is always found in the tip of the shoot (height not exceeding 18 inches). (*The Planter's Chronicle* 39, No. 1, 1944)

* * *

### New Method for Estimating Fertilizer Requirements of Citrus Trees

According to A. C. Bathurst in an article published in *Farming in S. Africa*, 18, 323-7, estimation of fertilizer requirements for crops by field experiments are accurate but slow and costly, by soil analysis cheap but vague. A promising method, that of plant analysis, is discussed. Three Transvaal citrus orchards received identical quantities of sulphate of ammonia. A responded by greatly increased yield, B showed a depressed yield, C was unaffected. Leaf analysis showed that A was deficient in nitrogen at the time of application, B had a very high nitrogen content while C was comparatively normal. From this and other experiments carried out by the author it is concluded that leaf analysis provides a cheap and relatively easy way of estimating nutrient requirements for most of the important plant foods, a conclusion which is supported by results obtained in other countries some of which are quoted. In citrus, amounts of plant food vary from leaf to leaf in any particular tree, chiefly according to the age of the leaf. To secure uniformity leaves for analysis should be taken during June and July (in South Africa) from the stalk of the fruit and directly up against it. These leaves will be ten to eleven months old. The author asks for leaf samples from growers all over the Union. He feels that if the requirements of their orchards could be thus ascertained a considerable saving of fertilizer, important at the present time, could be effected.